secretory disturbances. This remark applies to immediate results rather than to permanent benefits.

It is to be regretted that the cases in this series could not be observed for a sufficiently long period to determine the durability of the result and to determine whether a relation existed between improved physiological function and permanent cure or relief.

There is a large field for research still open along these lines. Much remains to be learned regarding the physiology and pathology of the stomach during and after medical treatment. It is only by close study and observation that we will learn to account for our failures and learn to recognize the factors that contribute to the clinical cure of these patients.

CLINICAL EXPERIENCE WITH SAHLI'S SPHYGMOBOLOMETER.[1]

By Nathaniel Bowditch Potter, M.D.,

DIRECTOR OF THE MEMORIAL LABORATORY AND CLINIC, SANTA BARBARA, CALIFORNIA; OFFICIER DE L'INSTRUCTION PUBLIQUE, MEMBRE CORRESPONDANT DE LA SOCIÉTÉ MÉDICALE DES HÔPITAUX DE PARIS; UNTIL 1918: PROFESSOR OF CLINICAL MEDICINE, COLUMBIA UNIVERSITY (COLLEGE OF PHYSICIANS AND SURGEONS); VISITING PHYSICIAN TO THE NEW YORK CITY HOSPITAL; CHIEF OF MEDICAL DIVISION OF ST. MARK'S HOSPITAL; CONSULTING PHYSICIAN TO THE NEW YORK THROAT, NOSE AND LUNG HOSPITAL, AND TO THE CENTRAL ISLIP HOSPITAL.

When this study was first begun nearly ten years ago it was with the purpose of applying a method of studying the circulatory efficiency of chronic diseases in measurable units, and so, of estimating the effect of drugs, of exercise, of rest, of food and of other extramedicinal measures, in order to prescribe any or all of them sufficiently accurately to promote the most rapid recovery, to continue the greatest efficiency and to avoid overloading the circulation.

Up to then no functional tests of the efficiency of the circulation, even as satisfactory as the modern functional tests of renal elimination, had been devised, especially for chronic invalids with damaged hearts, vessels and kidneys. The method of *Sphygmobolometry,* which the Swiss clinician founded upon the dynamics rather than upon the statics of the circulation, certainly promised much; and the later simplified and more accurate method of *Volume bolometry,* even more.

I purposely limited my two previous papers[2] of this series,

[1] From Memorial Laboratory and Clinic, Cottage Hospital, Santa Barbara, California.

[2] Potter, N. B.: Sahli's Pocket Sphygmobolometer; Demonstrated at a meeting of the Medical Section of the New York Academy of Medicine, November 19, 1912. Potter, N. B.: Sahli's Volume Sphygmobolometer; A Recent Improvement over the older Pressure Sphygmobolometer; Am. Jour. Med. Sc., October, 1918, No. 4, clvi.

practically to little more than a description of the instruments, awaiting a clinical contribution long expected from the Berne Clinic. Its place, however, has been usurped by highly technical articles which have from time to time appeared in various German journals of internal medicine, largely theoretical disputes between the erudite Director and one of his former pupils, Christen. Most modern clinicians, surfeited by carefully studied and prepared methods of exactitude, and instruments of precision, have acquired the habit of following lines of least resistance, avoiding polemic discussions, and largely utilizing only the exact, and the, so to speak, ready-made. This natural and mentally lazy tendency, and the incidence of the long war have unfortunately prevented, at most clinics, both here and abroad, the recognition as well as the application of this new conception and method of studying the circulation.

A THIRD INSTRUMENT. The writer's modification of the Volume Bolometer. After several years' experience with both of these

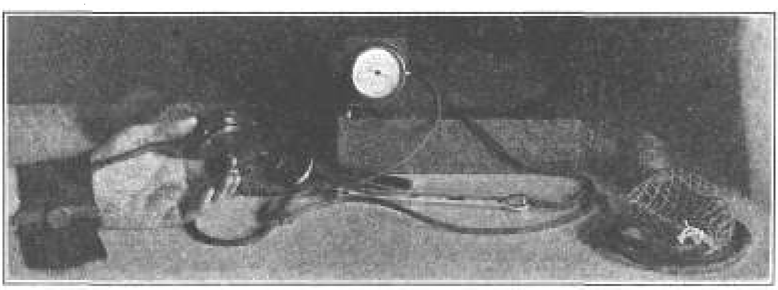


FIG. 1

instruments, the writer became convinced that a more compact and portable instrument, and one less liable to break in transportation could be made; in other words, one so conveniently constructed as to require no setting up and taking down each time it was used at a different place, and quite as serviceable for house-to-house practice as such American Sphygmomanometers as the Tycos and Sanborn instruments. The writer has, therefore, devised and had constructed, with the aid of one of his assistants, Dr. R. R. Newell, the simple modification exhibited in Fig. 1. It requires no further description than this illustration to make its advantages apparent. It enables the observer to take the blood-pressure immediately before or after he makes the Sphygmobolometer estimation, with the same spring manometer. It is so combined as to be very compact, portable and non-breakable, and can be applied, taken off, repacked in a box 10 x $4\frac{1}{2}$ x $2\frac{1}{2}$ inches and slipped into the observer's bag with the greatest ease and despatch. In this respect the writer feels

he owes a distinct apology to the distinguished inventor, knowing the latter's well founded objections to the substitution of a spring for a mercury manometer. If any reasonable demand for such a combined instrument occurs, Dr. Sanborn has been kind enough to offer to supply it.

A few paragraphs will suffice to dispose of the pressure bolometer, and perhaps this can best be done by quoting from one of Professor Sahli's personal communications. From our own point of view it is only necessary to inform the reader that we also had entirely substituted the latter for the former instrument, that some of the suggestions he so kindly gave us we find very helpful for the volume bolometer, as we did for the pressure instrument. We have made something more than a thousand observations with the pressure and two thousand with the volume bolometer, from which the data, tables and charts presented below have been collected. In the following charts and tables we have indicated observations which were made by the original pressure instrument; also those obtained with use of the volume bolometer by our group of workers in New York and at the Memorial Laboratory and Clinic, Santa Barbara, California. My reasons for this are, that although in the main our observations have proved uniform with both instruments and with both groups of workers, there has been, almost from the start, great difficulty and delay in obtaining duplicate instruments, fresh supply of rubber tubing, pelottes, etc., and the substitutes and crude repairs have been relatively so unsatisfactory, especially since the war, that some discrepancy in our figures has unavoidably occurred.

We may here quote from Sahli's personal communication:

"In regard to the comparison between the estimation of the 'Pulse Work' with Volume and Pressure instruments which you have again requested, I can add nothing to what I have already published. This proves that the two methods reveal approximately equivalent values for the pulse work; that the principle for both is correct and that if we employ sufficient care in the optimal adjustment of the cuff, and with the pressure instrument this detail is often tedious and difficult, we can obtain values for 'Pulse Work' which are clinically useful. Since these values in the figures published do not deviate much, one from the other, and since the optimal pressure with the proper application of the cuff does not usually vary markedly in the two methods, the pulse volume (considering the optimal pressures as equivalent) may be readily reckoned in pressure bolometry from the values for the 'pulse work.' 'Pulse Work' is equal to the 'Pulse Volume' times 'Optimal Pressure' times sp. gr. of hg. Perhaps, for the purpose of this communication, this last (sp. gr. hg.) has no significance, so that I have disregarded it.

"As far as your own estimated figures are concerned (a series of observations made upon some of my patients with the estimations and equations worked out in detail which I submitted to Prof. Sahli for criticism) your method of reckoning is correct. I have taken the pains to go over them all very carefully, and have found only quite unessential variations, probably due to the technique of your figuring."

For the reader who is interested the later bibliography upon the subject of Sphygmobolometry is appended below. There are, however, in addition to the Professor's own communication, several papers of considerable interest. The first,[3] from the Berne Clinic itself, concerns the combination of Sphygmobolometry and Jacquet's Sphygmography, for the details of which the reader is referred to the original article. The second,[4] from Naegeli's Clinic at Tübingen, in which a number of observations are reported. Many of them are made with the original pressure instrument, chiefly upon normal individuals, upon a series of long-distance runners before and after a test run, and upon oarsmen before and after a race. The majority showed a sharp rise in the work of the pulse at the end of the exercise, which he considers a normal response. A few showed no effect, or a diminution in the work, which he regards as evidence of a weakened circulatory reaction, and which he explains in one case by a drinking bout the night before, and in another by the remains of an old myocardial lesion.

The author, Hartman, tested four students before and after a drinking bout, with the uniform result of an increase in pulse-rate and drop in the pulse work. Again, he made numerous tests upon a few students after an excessive consumption of coffee, tea and nicotin, as well as many times after a moderately excessive ingestion of alcohol, practically always resulting in a considerable increase in the bolometric values. He concedes the difficulty of formulating a definitely normal value, but shows in four individuals how little the pulse work varies in one and the same individual, over a period of from five to six months. Upon the basis of measurements on fifty students, he formulates the normal between 6 and 14 g.cm. In older and stronger individuals the upper normal limit may reach as high as 15, and in younger males and in females, fall as low as $4\frac{1}{2}$. One of his experiments with twenty students shows how wide a variation may exist in the values obtained from the same individual, without any pathologic reason therefor. During the course of the spring season two measurements show approximately constant values, but the third time upon an extremely relaxing and

[3] Sahli: Ueber die Verwendung moderner Sphygmographen, speziell des Jaquet'-schen, zu sphygmobolometrischen Untersuchungen. Die Sphygmobolographie eine klinische methode, Corr.-Bl. f. Schw. Aerzte, 1911, Nr. 16.

[4] Hartman, Carl: Untersuchungen mit dem neuen Sphygmobolometer nach Sahli, Deutsch. Arch. f. klin. Med., 1915, Bd. 117.

oppressingly hot summer evening, sixteen out of the twenty showed an increase of from 1 to 2.5 g.cm. Most of those examined, including myself, very few of whom were physicians, felt the excessive filling of the arm veins. Upon a few pathological individuals before, during and after the use of digitalis, caffein, etc., his records, charts and the description of his work show careful, accurate observation, and are closely in accord with our own results.

He concludes as follows:

1. In perfectly healthy individuals the bolometer values vary excessively—from 6 to 13 or 14 g.cm.
2. The values in a single individual, however, remain remarkably constant over months.
3. Diurnal, physiological conditions, however, lead to not inconsiderable variations, which exhibit themselves characteristically with the bolometer conditions, even when no deviation can be shown by any other method. Therefore the analysis of Sphygmobolometric measurements, make our knowledge of physiologic, as well as pathologic, alterations considerably more profound than delicate.
4. The study of a continuous curve upon one individual, charted out over a considerable period of time, is especially valuable.
5. Physiological efforts, such as occur in sports, like long-distance running and rowing, will, if the test calls forth a moderate effort, produce a moderate increase in the bolometric value; a greater effort will produce a corresponding rise, and as the strength wanes, so too, does the bolometric value decrease.
6. The consumption of alcohol, tea, or nicotin exhibits similar alterations.
7. In the study of the capacity of the cardiovascular apparatus in pathological cases one obtains valuable conclusions from the bolometer.
8. Digitalis therapy gives successful results in the elevation of the bolometric values. When such decrease, so too, does the therapeutic effect of the drug.
9. Support in prognostic conclusions is afforded by this method, when all other methods fail.

Another important article is from the Clinic of the master himself.[5] Regarding this article Sahli wrote me as follows:

"It was not until Dr. Dubois had almost completed his thesis upon pressure bolometry that volume bolometry originated, so he was unable to utilize it. It was soon evident that most of his values were lower than the corresponding volume bolometric values."

"Unable to oversee his work minutely I cannot be sure that each estimation was made with an optimal application of the cuff; nevertheless his clinical observations are quite serviceable if limited to the comparison of one and the same individual at different times, since

[5] Dubois: Sphygmobolometrische Untersuchungen bei Gesunden und Kranken. Deutsch. Arch. f. klin. Med., 1916, Bd. 120.

the chief defect depends upon the anatomical configuration of the wrist-joint region, and so in the estimations upon the same person the figures vary but slightly. Although he had estimated a large series of normal values, at my insistence they were not included in his publication because my assistant, da Cunha, will establish these for volume bolometry alone and later on will publish them. I do not want to cause confusion by presenting two sets of normal values."

The article of da Cunha[6] to which Sahli refers, gives us normal values for the volume of the pulse and for the pulse work, which, despite the inherent difficulties of the method and its interpretation, are of no little utility in the estimation of pathologic cases. Da Cunha's summary follows:

Statistics for normal males, age sixteen to forty-nine years:

Radial pulse volume: Maximum, 0.15 c.cm.; minimum, 0.05 c.cm.; average, 0.09 c.cm.

Radial pulse work: Maximum, 17.14 g.cm.; minimum, 6.12 g.cm.; average, 11.27 g.cm.

Minute's volume of radial pulse: Maximum, 11.2 c.cm.; minimum, 3.0 c.cm.; average, 6.81 c.cm.

Statistics for normal females, age sixteen to forty-nine years:

Radial pulse volume: Maximum, 0.11 c.cm.; minimum, 0.04 c.cm.; average, 0.07 c.cm.

Radial pulse work: Maximum, 17.95 g.cm.; minimum, 5.98 g.cm.; average, 10.19 g.cm.

Minute's volume: Maximum, 8.8 c.cm.; minimum, 2.4 c.cm.; average, 5.56 c.cm.

After a seven o'clock breakfast, taken in bed, the pulse-rate increases, but there is little variation in the volume and work of the individual pulse. Half an hour after a large midday meal the volume and work of the individual pulse, rise, whereas the pulse-rate remains stationary. Two hours after the midday meal the pulse volume resumes its original value. The pulse work likewise decreases, but not with the same regularity. It may return to its original value or it may fall slightly above or below it. The rate of the pulse is now lower than before the consumption of food.

Charts 13 and 14 illustrate my own observations on normal or approximately normal subjects before and after the noon meal.

On changing from a lying to a sitting posture there is an acceleration of the pulse, but in both pulse volume and pulse work there is a decrease so great that, despite the increase in pulse-rate, there is a distinct fall in the minute's volume and the minute's work.

My observations in regard to posture are illustrated by Chart 6.

Da Cunha's article shows that his work was done in the usual

[6] da Cunha, D. Jose: Beiträge zur Beurteilung der Resultate der Sahli'schen Volumbolometrie nach Untersuchungen bei Gesunden, Corr.-Blatt f. Schweizer Aerzte, 1917, Nr. 46.

accurate fashion of the Berne Clinic. Most of his observations are quite in accord with our own. His illustrations are unusually simple, clear, and striking. This paper should be consulted by anybody planning to utilize the instrument and the method.

On account of the war, four of the more recent publications[7] have been, and still are, inaccessible to the reader on this side of the water. However, Reinhart's very recent article[8] reveals much of what is most essential. Reinhart regrets the extreme paucity of the literature.

Brösamlen entirely discards the method because of the influence exerted upon the values he obtained by varying vasomotor conditions. He denies that any conclusions of permanent value in regard to the cardiac-systole can thus be obtained. In his last communication Sahli replied to the above criticism, pointing out the incomplete and incorrect protocols upon which Brösamlen's conclusions were based; also his entire neglect of the pulse-rate, and failure to report the pulse volume in addition to the work. Individual variations of the caliber of the radial artery, as induced by the effect of heat and cold upon the arm, may of course have been responsible for considerable fluctuation in the pulse volume, and so too, may general vasomotor influences. Sahli believes, however, that, taking all factors, such as pulse-rate, into consideration, dependable values for the measure of the volume of the circulation can be obtained, unless there are gross vasomotor or anatomical abnormalities of the radial artery.

Reinhart, using the new sphygmovolumeter with great care as to application of the cuff, endeavored to determine, by simple experiments in which the volume of the heart-beat could be considered positive, whether a demonstrable increase or diminution of the systole would also be manifested in an increase or diminution of the sphygmovolumeter volume. Working with large and small hearts, on the theory that, aside from anomalies such as mitral insufficiency, a larger heart must be associated with a larger heart-beat volume, the author obtained results which conformed in every respect with the roentgen-ray findings. In 130 examinations made with the sphygmovolumeter on 30 normal individuals and 25 patients with valvular lesions, this author demonstrated the fact that the volume of the pulse diminishes as the patient changes from horizontal to

[7] Brösamlen: Die Bedeutung der Pulsuntersuchung f. die Bemessung des Herzschlagvolumens, Deutsch. Arch. f. klin. Med., 1916, Bd. 119. Dubois: Sphygmobolometrische Untersuchungen bei Gesunden und Kranken, Deutsch. Arch. f. klin. Med., 1916, Bd. 120. Müller, O., und Brösamlen: Ueber die Eignung der Sphygmobolometrie resp. Sphygmovolumetrie zur Bemessung der Systoleagrösse resp. des Minutenvolumes, Deutsch. Arch. f. klin. Med., 1917, Bd. 124. Sahli, H.: Ueber die richtige Beurteilung der Volumbolometer und die Art ihrer Klinischen Verwendung zugleich Erwiderung auf den Aufsatz von Dr. Brösamlen, Deutsch. Arch. f. klin. Med., 1917, Bd. 122.

[8] Reinhart, A.: Ueber die Eignung der Sphygmovolumetrie zur Bemessung der Systolengrösse, Deutsch. Arch. f. klin. Med., 1918, vol. cxxvii.

the upright position, corresponding directly with the diminished size of the heart in the upright position. This decrease averaged 20 per cent. to 30 per cent., but in individual cases amounted to 45 per cent. to 50 per cent. in special patients. In these experiments, as the volume decreases the pulse-frequency rises, thereby partly, but not entirely, compensating in minute's volume for the reduction in size of the single pulse. Corresponding with the diminution of the volume, the maximal pressure also drops as a rule 10 to 15 mm. of mercury.

In a series of experiments with the Valsalva test, Reinhart demonstrated a diminution of the sphygmovolumetric pulse volume conforming with the decrease of heart-beat volume demonstrated by the roentgen ray. This diminution of the pulse volume points to a diminution of the heart-beat volume, and, *vice versa*, a diminution of the heart-beat volume points to a diminution of the pulse volume.

In a third series of experiments, it was demonstrated that fluctuations in the pulse volume occur under forcible inspiration and expiration. In pulsus paradoxus and respiratory arrhythmia the smaller systoles at the beginning of the inspiration were associated with smaller pulse volumes. Sixty cases without respiratory arrhythmia showed, with few exceptions, a decrease in the pulse volume at the beginning of inspiration, corresponding to the theoretical decrease in the systole on inspiration.

In his fourth series of experiments the author found that in changes of frequency of cardiac contractions, induced by stimulation or paralysis of the vagus nerve, by means of pressure and of atropin respectively, the high-frequency contractions were accompanied by smaller pulse volumes than were the low-frequency contractions.

Finally, it was shown from pathological cases that pulse volume is dependent on heart-beat volume; as in cases of compensatory disturbances with a small systole and in pulmonary edema with failure of the left ventricle, where a distinct diminution is noted in the volume of the pulse, pulse volume again increasing under improvement of the circulation.

Reinhart, then, in his carefully executed experiments, establishes that the pulse volume as measured by sphygmovolumetry is directly dependent on the size of the systole; hence the pulse volume registered by the sphygmovolumeter affords a method for determining the size of the systole. These experiments seem positively to refute the violent attack made upon sphygmovolumetry by O. Müller and Brösamlen.

What is this dynamic measurement? Is it of clinical value, sufficient to justify the amount of training, patience and time essential to its employment? It was not until some years after *Sphygmomanometry* had been demonstrated to be an essential addition to any physical examination, that it was proved beyond peradventure

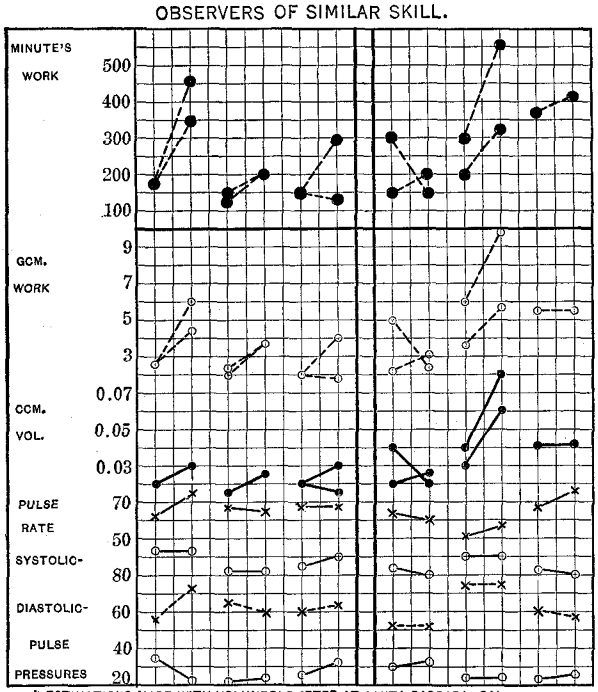
that even an expert could not estimate blood-pressure with any degree of accuracy by ordinary finger palpation of the artery alone, although this had formerly been supposed possible. For centuries every physician has been palpating the pulse in order to be able to determine by the pressure of his finger an approximate value of *pulse volume* and indirectly, although generally unwittingly, a rough measure of *pulse work*. Without discussing the value of such dynamic pulse conceptions, or even whether they do actually furnish determinations of the same relative value as for the heart itself, it may be stated positively here that none of us who have been working with these instruments have the slightest doubt that the ordinary finger palpation of the pulse is incapable of furnishing even a skilled observer much if any more dependable results in this dynamic measurement than, unaided by an instrument of precision, he is able to obtain of blood-pressure with its static measurement. If we can prove, therefore, that these dynamic measurements are of clinical value, either in diagnosis, prognosis, or treatment; that they can be reasonably accurately determined by Sahli's latest instrument, the so-called *Volume bolometer;* that the essential skill and experience for its use can be obtained by any competent clinician or laboratory technician within a brief period; and that the procedure requires but a moderate amount of time for each estimation; we shall then have definitely demonstrated that the fecund Swiss clinician has added another and a most valuable method for accurately studying the circulation, and one from an entirely new viewpoint. The older method *Sphygmobolometry* or *Pressure bolometry* has been entirely discarded by its originator at his Clinic at Berne and permanently supplanted by *Volume bolometry.* Our observations, however, with the earlier method may be utilized in a tabular and statistical form to prove that even with this inferior, much less accurate, and much more time-consuming method, quite dependable results were obtained by my assistants after but a few weeks' training and experience.[9]

With the aforesaid purpose in view, we have, therefore, made no special or definite effort to establish a table of normals, based upon either decade, sex, size or weight; or to more than point out such gross differences in both *pulse work* and *pulse volume* as are well exhibited by such cases as an emaciated, weakened, starving diabetic, well-compensated aortic insufficiency, essential high blood-pressure, or an enormously hypertrophied heart from long-standing chronic nephritis. Such differences will be frequently noted in the

[9] I acknowledge with much appreciation and thanks the devotion, patience and industry of Drs. Bradbury, Ordway, Brownlee, Ramurez and others who made these observations from which these tables and statistics were collected. Before their results were fairly uniform and trustworthy, each one of them required from three to eight weeks' practice, depending largely upon their previous experience with instruments of precision. Of course their observations were not utilized until they had developed this degree of skill.

figures below. After several years' experience I believe that this new method of studying the circulation will prove to be of essentially more value in comparing the daily figures furnished by a single case, or of the effects of various methods of treatment, medicinal or extra-medicinal in some one individual than in helping us to diagnose the disease in question or even to compare one patient with another by a single bolometric determination upon each. In the first place a number of determinations would always be necessary in order to

COINCIDENT OBSERVATIONS BY *
OBSERVERS OF SIMILAR SKILL.



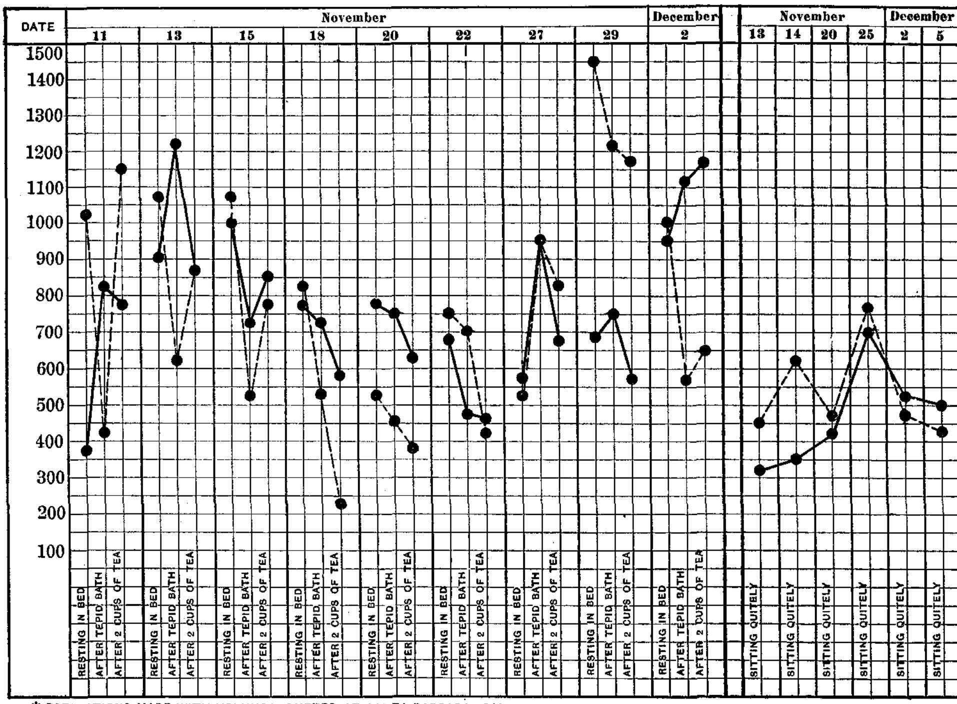
* ESTIMATIONS MADE WITH VOLUMBOLOMETER AT SANTA BARBARA, CAL.

CHART 1

arrive at an approximately uniform figure for this or that individual patient's normal. In the second place each patient's normal radius is relatively wide, especially so as compared with the border limits, and is influenced by many temporary, even momentary, emotional and other unavoidable causes. However, after what may be called the normal variations for an individual are once determined the effect of various causes when measured in *gram-centimeters of* WORK, or better still of MINUTE WORK, should prove of considerable clinical value.

ACCURACY. Chart 1 shows the results of coincident estimations on opposite wrists of the same individual by two observers of reasonably similar skill and experience. As will be seen in most instances, the agreement is striking. Where such wide discrepancies result as the last reading on Case 1, and the first reading on Case 2, it is generally because of the differences of the size and position of the radial artery, perhaps most often the latter; for in the many emaciated diabetic patients upon whom most of these tests were

CHART OF MINUTE'S WORK ON DIABETIC AND NORMAL
TWO OBSERVERS OF DIFFERENT SKILL*



* ESTIMATIONS MADE WITH VOLUMBOLOMETER AT SANTA BARBARA, CAL.

CHART 2

made, the difficulty of adjusting the wristlet properly is almost insurmountable, requiring infinite time, patience and frequent repetitions.

Chart 2 shows the variation between similar observations made by observers of markedly different skill and experience.

Chart 3 compares graphically the percentage of variations in the two wrists when the observations were made by the same worker under as nearly as possible identical conditions, the one immediately after the other, utilizing systolic, diastolic and pulse-pressures and

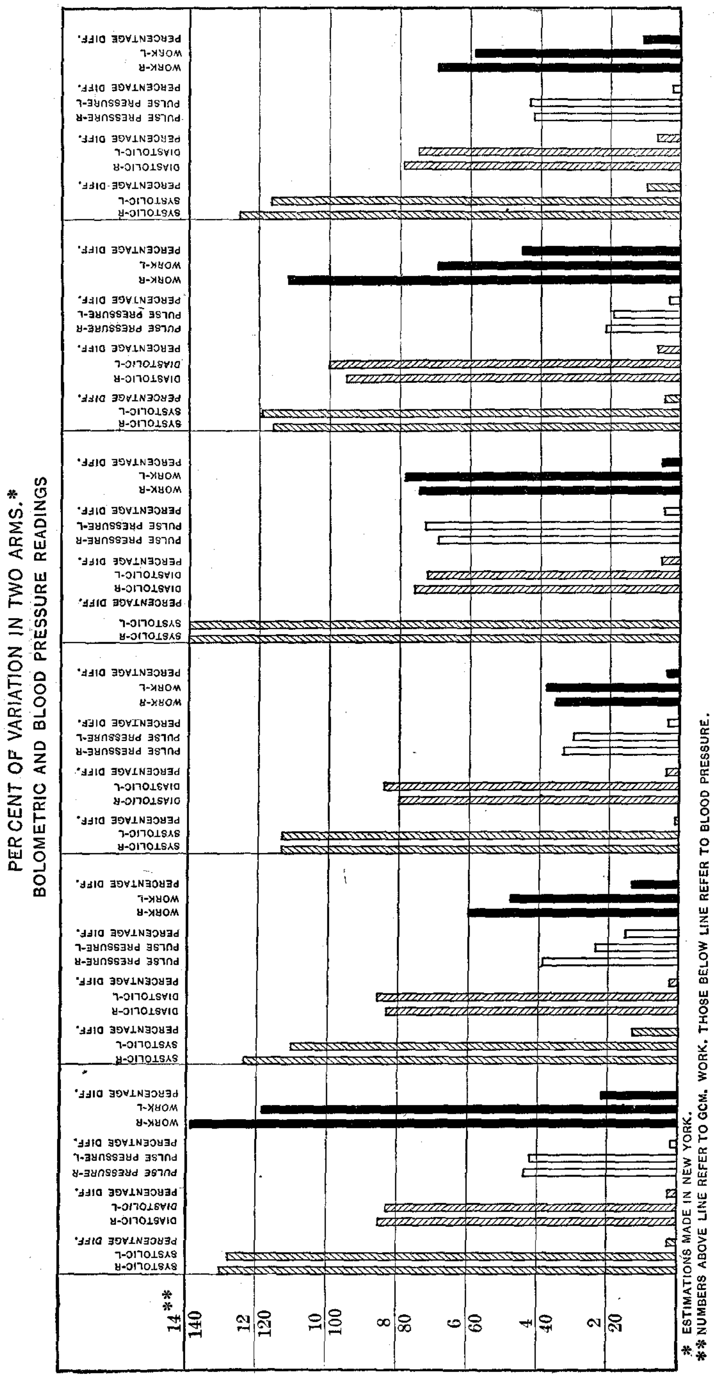

PER CENT OF VARIATION IN TWO ARMS.*
BOLOMETRIC AND BLOOD PRESSURE READINGS
SYSTOLIC-R
SYSTOLIC-L
PERCENTAGE DIFF.
DIASTOLIC-R
DIASTOLIC-L
PERCENTAGE DIFF.
PULSE PRESSURE-R
PULSE PRESSURE-L
PERCENTAGE DIFF.
WORK-R
WORK-L
PERCENTAGE DIFF.
14**
140
12
120
10
100
8
80
6
60
4
40
2
20
* ESTIMATIONS MADE IN NEW YORK.
** NUMBERS ABOVE LINE REFER TO GCM. WORK, THOSE BELOW LINE REFER TO BLOOD PRESSURE.

CHART 3

work. Although the blood-pressure is much more in conformity, yet the difference is not striking.

Thus it may be concluded that there is scarcely less of accuracy or variation in this modern method *Volume bolometry* than in *Sphygmomanometry*.

TIME REQUIRED TO BECOME EXPERT. Prof. Sahli states ten minutes, but this time varies so greatly with the individual technician that it is difficult to obtain definite figures. My experience, however, with the many assistants who have so devotedly aided me in this study has led me to conclude that, like most other painstaking methods of precision with relatively delicate instruments, the whole affair is largely a matter of temperament, considerably a matter of training in similar methods, and no little dependent on the great quality of patience. From twenty-five to one hundred estimations usually fit a competent, well-trained technician to make dependable estimations.

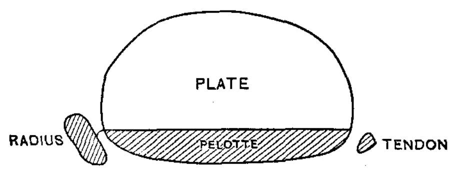


FIG. 2

TIME EXPENDED UPON EACH DETERMINATION. Each determination requires, according to the speed of the technician, and the type of patient, especially the position of his radial artery, upholstery of fat about the tendons, and configuration of his wrist, from two to three times that required to perform a systolic and diastolic blood-pressure determination by the usual auscultatory method with the Tycos or Sanborn instrument.

APPLICABILITY, CONVENIENCE AND ANNOYANCE TO THE PATIENT. Delirious patients with pneumonia, thrashing about continually, render such estimations extremely difficult, or impossible; but the ordinary quiet delirium of typhoid fever, or pneumonia, scarcely increased the difficulty of its application. The essential importance of a placid temperament in the observed as well as in the observer is self-evident. In Charts 13, 14, 15 and 16 any reader can readily select which of the observed individuals belong to this enviable category and which have an emotional, excitable, unstable nervous system. Variations in *Minute Work* represented by more than 100 per cent. have been observed to follow such slight nervous influences as the interruption of a telephone message. After all, it is wise to keep in mind that one essential feature of the greatest importance in the correct interpretation of incongruous results should first be attributed to the configuration of the wrist and to the

varying application of the cuff. In this respect, Prof. Sahli wrote me the following helpful suggestions:

"Great variations in the configuration of the tissues at the wrists of different individuals is responsible for one of the most telling difficulties in each application of the cuff for a proper optimal pressure. In one person the application is extremely easy, in another much patience and time are required on account of the way the plate is supported on one side by the styloid process of the radius and on the other by the tendon of the flexor carpi ulnaris, bridging over to a certain extent the pelotte in an excavation of the plate, thus:

"One frequently applies the plate *farther up* the arm because in bony and tendinous individuals it is impossible to succeed at the usual point of application, whereas, in addition to the separation of bone and tendon higher up, the better upholstered soft parts are also of assistance. Another help is sometimes afforded by *revolving the plate* along its long axis.

"The *throttled manometer* which I formerly employed to avoid a loss of energy, proved superfluous and I discarded it. It too may be responsible for mistakes in pressure values because *sometimes with the higher pressures it does not register correct values.*

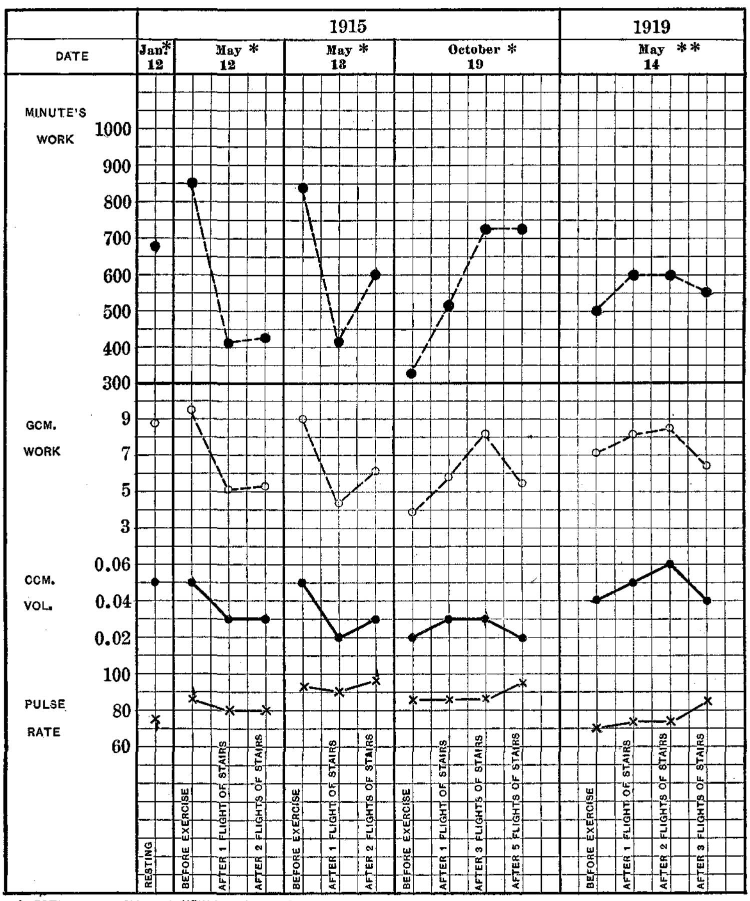
"The *glass connections,* too, must be of the same very small calibre. All these affect the multiplication factor, ϕ, which only applies to the caliber, the length of the conducting tubes and the air content of the system above mentioned. Though very impractical, leaden tubes would be preferable to rubber tubes in pressure bolometry.

"In pressure bolometry spontaneous relaxation of the cuff must be carefully avoided, for despite its very good application the vigorous pulsating force exerted, may gradually cause it to yield and even to become definitely distended. This change is much less liable to occur in volume bolometry because of the much less decided variations in pressure. As a result of such yielding there may arise materially incorrect (too small) pressure bolometric values.

"Certain possible errors may occur even in the reading. As you have noted yourself, they depend upon the effect of the variations in the respiration and of Traube's waves (periodic vascular contractions) continually dislocating the index and altering the size of the excursions. Hence, when the excursions are small much practice is needed to read them accurately, especially in pressure bolometry. So, too, the endpoint of the excursions is difficult to determine in the frequently lightning-like rapidity of the pulsations, because the retinal impressions are so transitory that one scarcely appreciates the index endpoint which persists near the latter so very brief an instant as to produce scarcely any color appreciation. This difficulty is all the more accentuated because the extremity of the index is not a straight cross line, but a sort of swollen meniscus

scarcely visible, as a result of the rapidity of the motion. The *lower meniscus* less bowed than the upper is, therefore, more easily read and gives frequently higher readings than the upper. The same difficulty occurs in both instruments, but is more significant in pressure bolometry where the absolute size of index is less. Since

PERMANENCY OF PULSE WORK



* ESTIMATIONS MADE IN NEW YORK
** ESTIMATIONS MADE IN SANTA BARBARA, CAL.

CHART 4

the difficulty is repeated at both the upper and the lower ends of the excursions, errors in reading of as much as 1 mm. may readily occur with rapid pulsation, and, *e. g.*, at an optimal pressure of 10 cause variations of about 2 g.cm. I attempted to facilitate the readings in very rapid oscillations by employing a diminishing loop

and so reducing the rapidity of the retinal impression, but the experiment had the drawback of diminishing at the same time the absolute measure. Errors may also arise if the system is not perfectly tight, and unnoticed the pressure gradually falls during the observations and the reflux index movement resulting from the falling of the pressure is then superimposed with consequent too

PERMANENCY OF PULSE WORK

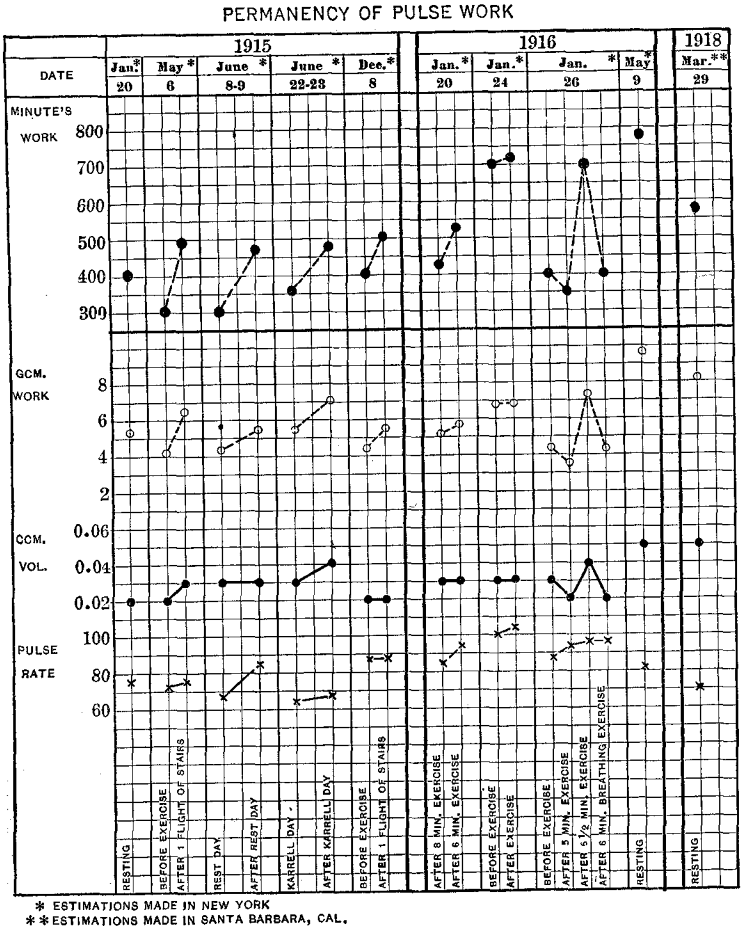


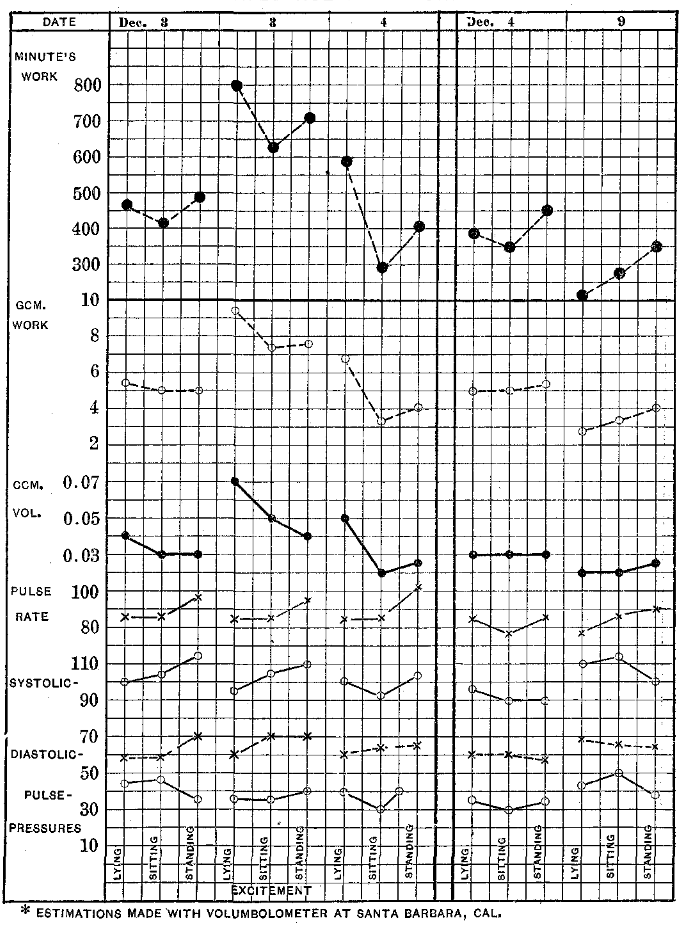
CHART 5

low values. In pressure bolometry this possibility of error is, on account of the smaller excursions, of greater significance than in volume bolometry. Besides, the optimal pressure frequently falls very rapidly without being noticed and too low values are thus read off.

"The most important cardinal points after all, are:

Insufficient tension of cuff;
Deficient rigidity of rubber tubing;
Loosening of the cuff;
Leaking in the system;
Reading errors on account of the rapidity of excursion and the obscurity of the index meniscus with the rapid movement.

INFLUENCE OF POSTURE*



* ESTIMATIONS MADE WITH VOLUMBOLOMETER AT SANTA BARBARA, CAL.

Chart 6

"In the final result of the estimated pulse work all these cause negative errors which are responsible for the unsatisfactory results that you describe. In general it is evident that with a strong pulse

and high values of pulse work the loss of energy is more difficult to prevent than with low values.

"It seems to me that you can very well utilize your own clinical observations in so far as they concern comparative observation on the same patient, but I should much regret your publishing incorrect

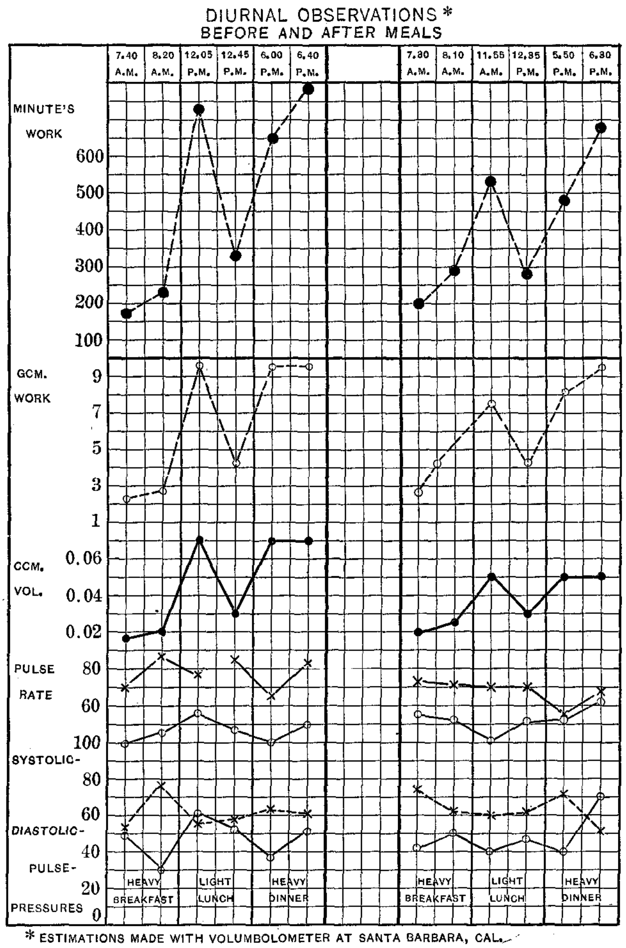


CHART 7

results, the cause of which errors I have just explained. Such results would better be withheld. Confusion would only result and not only pressure bolometry, but all sphygmobolometry be freshly discredited. The general medical public is neither discriminating nor sufficiently oriented to draw correct, even if not entirely erro-

neous, conclusions. Hence, I do not believe such an inclusion would accomplish the purpose mentioned in your letter, of furthering the method. Sphygmobolometry merits support, and although it has

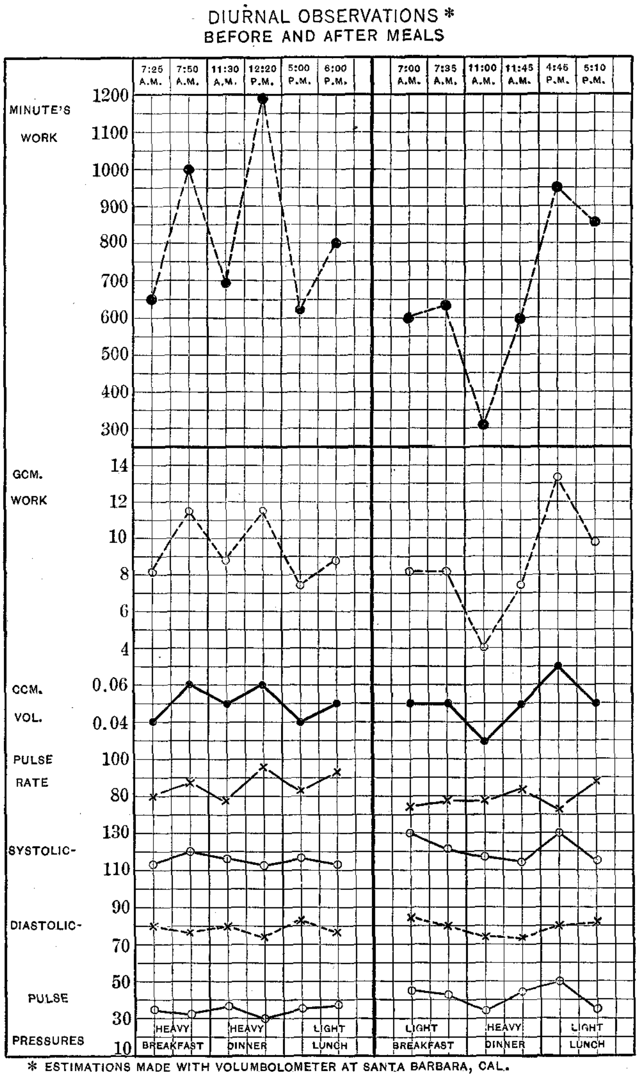


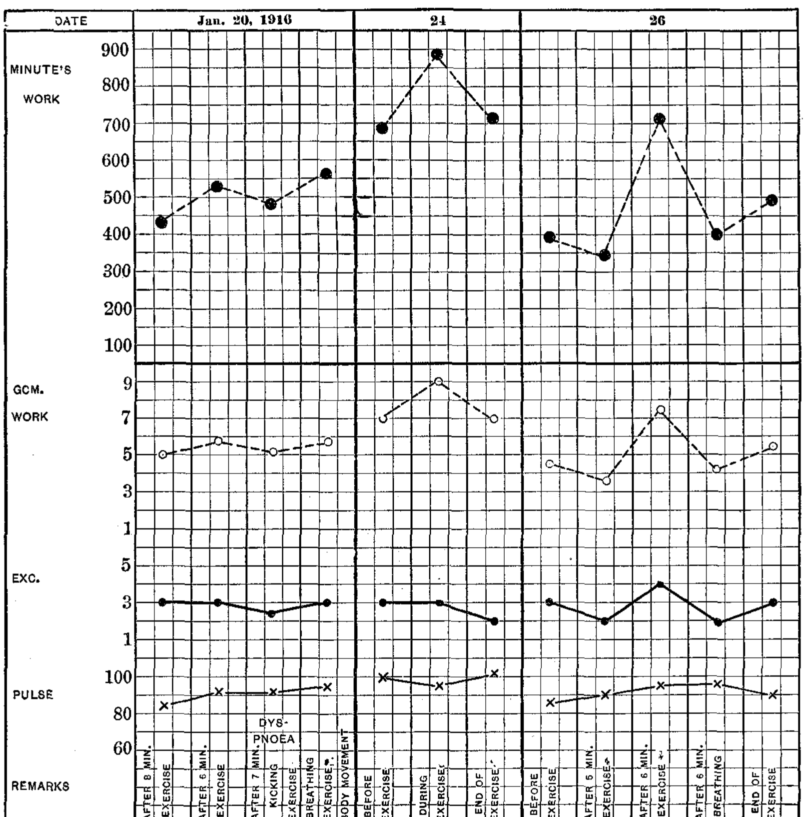
CHART 8

not yet attained an undisputed place in stricken Europe, it should acquire such recognition in unprejudiced America. For the moment most of the great medical public unintelligently regard the method

as entirely useless, but I am convinced that eventually sphygmobolometry will entirely reform clinical hydraulics, although by then I shall probably have passed away."

One final caution, from the patient's standpoint, is worth mentioning. I have repeatedly observed, especially in high strung, sensitive patients, with high blood-pressure and broad excursions

INFLUENCE OF EXERCISE*



* ESTIMATIONS MADE IN NEW YORK

CHART 9

of the transmitted beat, so decided a trepidation, dread, or fear while watching this lively, extensive oscillation of their own pulses as to render any such series of determinations quite inadvisable from the point of view of their proper treatment. It seems to have quite the same effect as in the old days when similar patients builded their happiness or misery upon the presence or absence of albumin and casts in their urine.

Permanency of an Individual's Pulse Work. Charts 4 and 5 tend to show that in the ordinary individual the figures for the Work or Volume do not vary to any striking degree, in the course of a brief number of years. Most of these observations were made

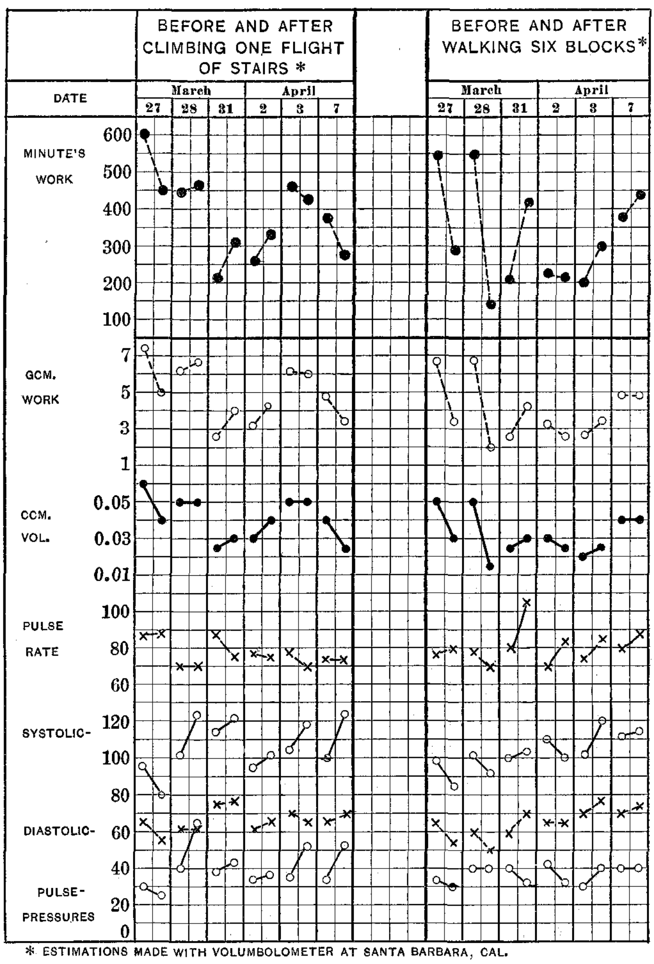


Chart 10

before and after various forms of exercise, and although the response to exercise may vary with variations in the patient's condition, the limits within which these variations occur remain fairly constant, in spite of the fact that observations were made both in New York

and in Santa Barbara, California, with entirely different instruments and several different observers.

VARIATIONS DEPENDENT UPON EXTRAMEDICINAL INFLUENCES. Pulse volume and heart work vary with the ordinary daily procedure and happenings of normal life, such as posture, activity, exercise,

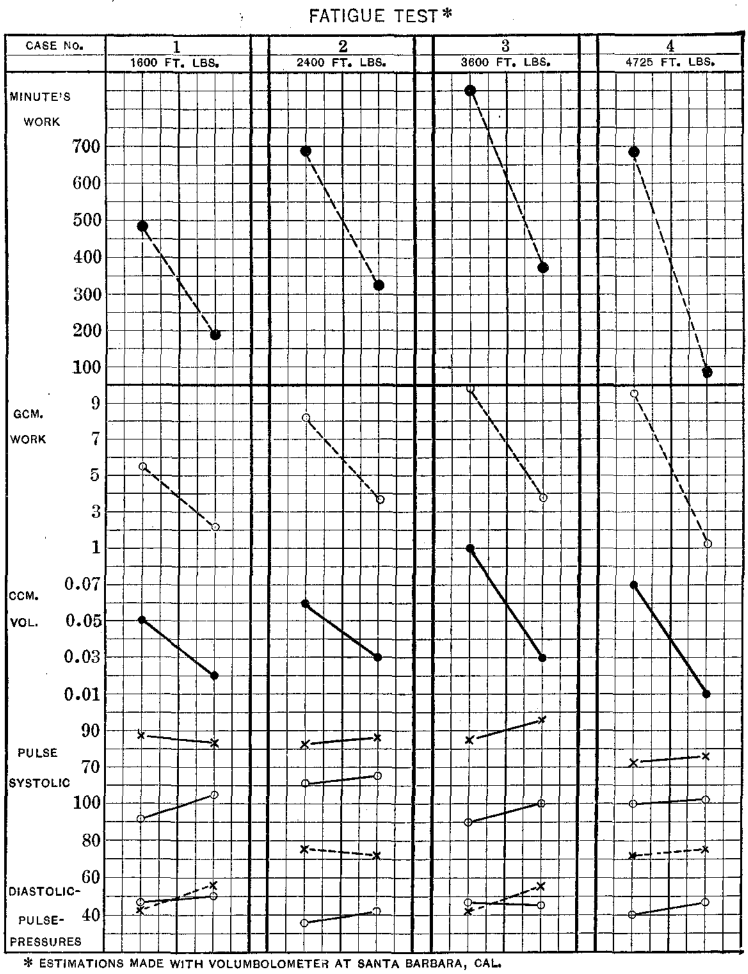


CHART 11

eating, drinking, bathing, nervous excitement, rest, fatigue, etc., so that to determine if one or both of these definitely measurable dynamic qualities of the pulse can be utilized in estimating circulatory efficiency, we have made a certain number of estimations upon

normal and diseased individuals before and after such influences. It ought to be helpful, for example, if a certain individual can run up so many stairs in a given time and show no effect of fatigue; and if an increase in the number of stairs, or the speed with which they are traversed results in a moderate increase in *minute work*, we would presumably consider the circulatory response as relatively efficient; but if, at the second flight of stairs, the *minute's work* which

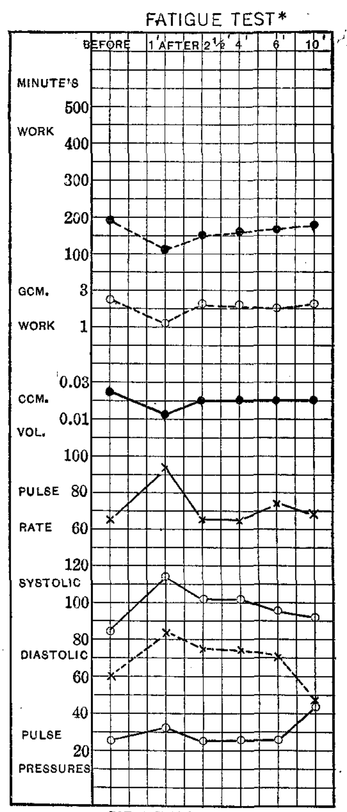


CHART 12

had been moderately increased after one flight, suddenly fell, and especially if at the same time the pulse-rate considerably increased, such a result would evidently mean fatigue, and point to a relatively inefficient circulation.

Chart 6 exhibits the difference in *minute's work*, in two normal individuals in the horizontal, sitting and vertical postures. In changing from a horizontal to a sitting posture there is typically a

considerable decrease in minute's work, which is usually brought about by a decrease in pulse volume. The minute's work increases again, however, when the subject assumes the vertical position.

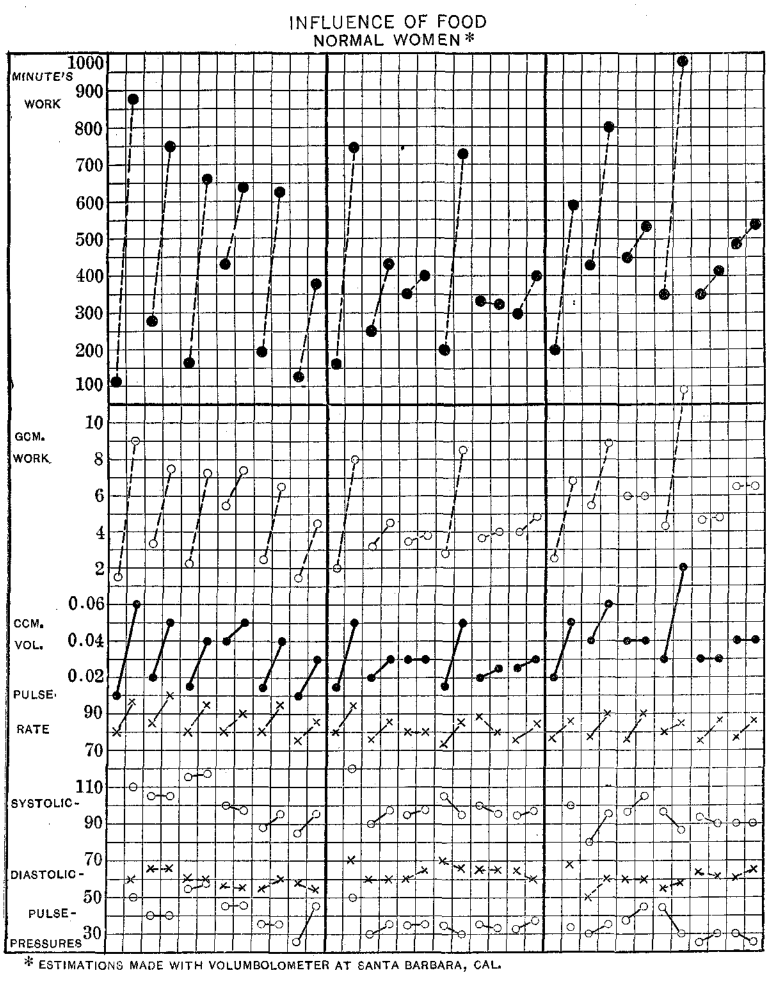
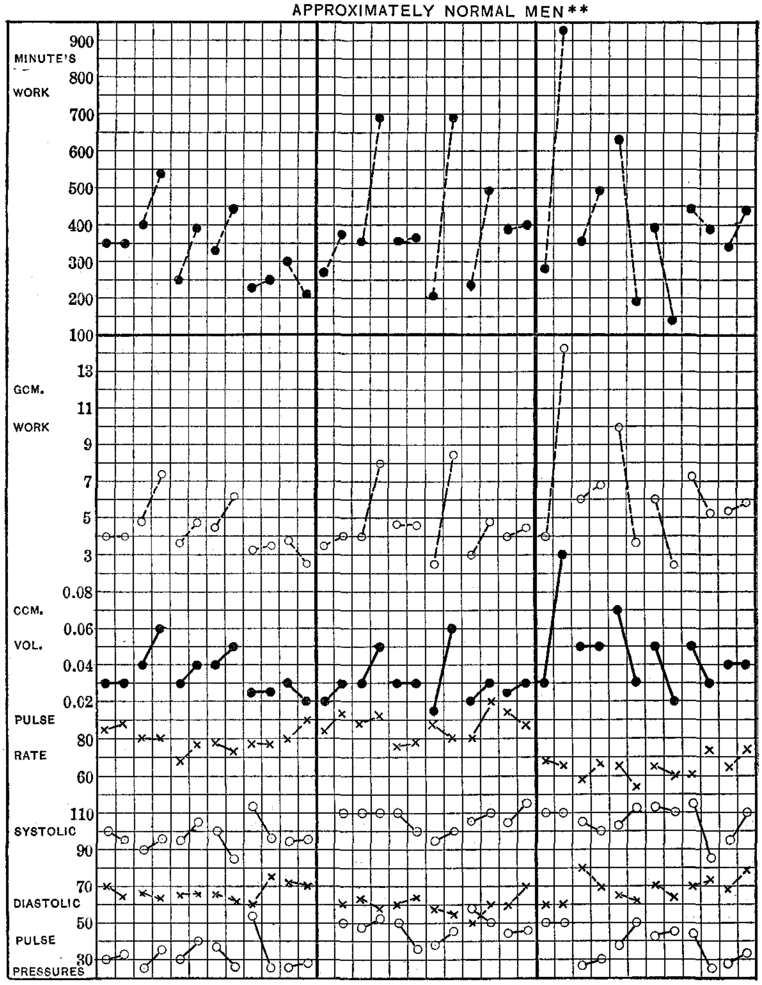


CHART 13

Charts 7 and 8 represent the difference in *minute's work* in four individuals in the early morning, before breakfast, after breakfast and before and after the midday and evening meals. The similarity of the curves in Chart 7 is quite striking. The lowest points of the curves of work, minute's work and volume are all at the early

morning reading. This is followed by a slight rise after the ingestion of food. The activities of the day and increase in temperature of a very relaxing summer day, result in markedly higher readings

INFLUENCE OF FOOD*
APPROXIMATELY NORMAL MEN**



* ESTIMATIONS MADE WITH VOLUMBOLOMETER AT SANTA BARBARA, CAL.
** CASE 1, NORMAL; CASE 2, MILD DIABETES; CASE 3, ARRESTED TUBERCULOSIS

CHART 14

at noon, but these high readings are followed by a drop after the noon meal. In the evening again the readings are high, followed by a further increase in minute's work after the evening meal, this

increase being due to an increase in pulse-rate rather than to any change in volume. The observations illustrated by Chart 8 were made upon nurses, interrupted at their work, where influences other than food were probably present. There is, however, a general

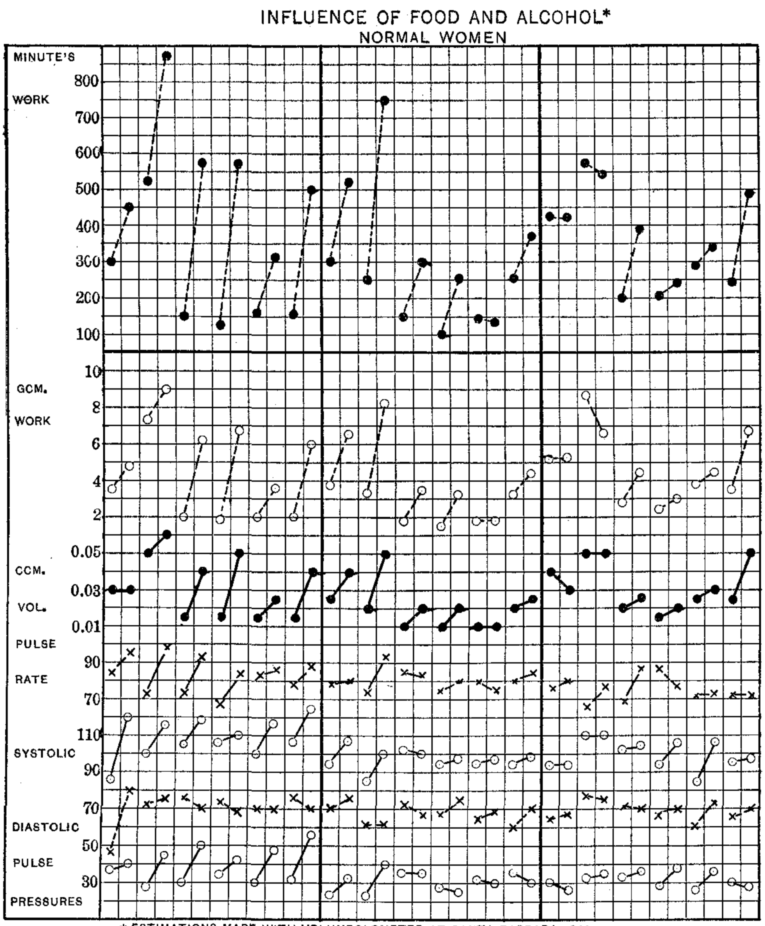


CHART 15

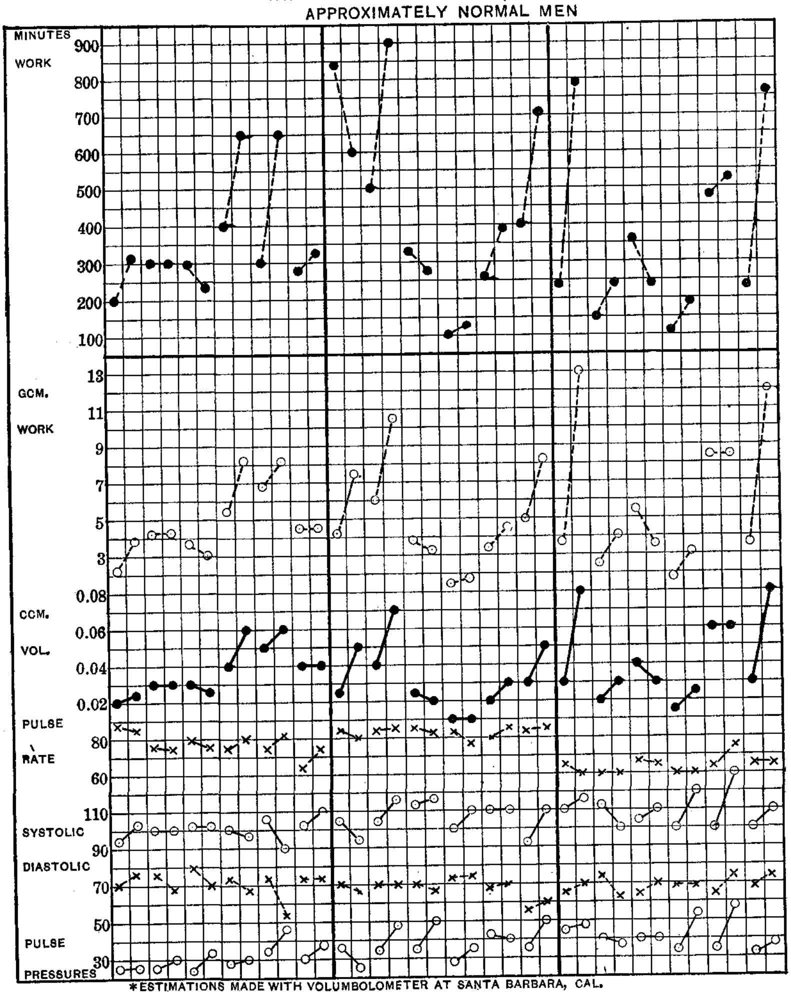
tendency for the minute's work to increase after meals. These observations were made on a cool, bracing day when there was little change in temperature during the day.

Charts 9 and 10 represent the effect of some different types of exercise in two normal individuals. Here the normal reaction to exercise is an increase in minute's work, generally accompanied by

a corresponding increase in gram centimeter's work and in volume. Where there is a decrease in minute's work it indicates fatigue.

Chart 11 shows the effect of fatigue on four normal subjects. The readings were taken before and as soon after exercise as it was

INFLUENCE OF FOOD AND ALCOHOL*
APPROXIMATELY NORMAL MEN



*ESTIMATIONS MADE WITH VOLUMBOLOMETER AT SANTA BARBARA, CAL.

CHART 16

possible to adjust the cuff; thereby obtaining a marked decrease in work and minute's work.

Chart 12 shows the effect of fatigue and the gradual return to

normal after the initial decrease in work. Readings were taken at intervals of one minute, two and a half, four, six and ten minutes after exercise.

Charts 13 and 14 represent the effect of food in six individuals. There is generally a marked rise in minute's work, gram centimeter's work and volume after the ingestion of food; and this is especially well shown in Chart 13 where the subjects are more nearly normal than those of Chart 14.

Charts 15 and 16 represent the effect of food in these same individuals, under similar conditions, at the same time of day, when this food was supplemented by a certain amount of alcohol. There is less regularity in the results obtained in these two charts than in the two preceding, uncomplicated food charts, but the general or average tendency toward a rise after the meal is the same.

SUMMARY. 1. It is evident that the method of volume bolometry is relatively simple, easily applicable, not unduly time-consuming and of at least practical accuracy.

2. To determine whether the results obtained therefrom are sufficiently valuable either in estimating circulatory efficiency, *i. e.*, a functional circulatory test, or in following, or judging the effect of medicinal, or extra-medicinal methods of treatment, more clinical experience under a greater variety of conditions must necessarily be available.

3. It suggests a new conception of the circulation and certainly is worth further study.

4. It is better adapted to clinic or perhaps to office practice than to routine private practice at a patient's home.

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THE RAPIDITY AND PERSISTENCE OF THE ACTION OF DIGITALIS ON HEARTS SHOWING AURICULAR FIBRILLATION.[1]

By G. Canby Robinson, M.D.,
ST. LOUIS, MISSOURI.

(From the Department of Internal Medicine, Washington University School of Medicine, St. Louis, Missouri.)

The fact that digitalis requires many hours or even days to affect the heart when given in the usual doses, has been perhaps the chief disadvantage in the use of the drug in cases of heart disease in which prompt action is urgently indicated. It is well known that repeated doses must be given before the action of the drug manifests itself, and it is often difficult to determine accurately when the action begins. There has also been considerable discussion as to how long the drug remains effective after its administration is stopped, a point of important bearing on the so-called cumulative action of the drug.

In order to gain further knowledge regarding these questions, the effect of large single doses of digitalis has been observed on a selected group of patients suffering from a form of cardiac disorder which is definitely influenced by the drug. All the cases studied were demonstrated by electrocardiograms to suffer from either auricular fibrillation or auricular flutter, and in all the ventricular rate was abnormally rapid. Care was taken in every case to make sure that the patient was not under the influence of digitalis when the large dose was administered, either by the history, or the statement of the physician sending the patient into the hospital, or by a period in the hospital of at least ten days without the administration of the drug.

Digitalis was given by mouth in the form of the tincture and the dose was regulated according to the method worked out by Eggleston.[2] The underlying principle of this method is to give in one or several frequent doses the entire amount of the drug which may be expected to produce the maximum therapeutic effect. The tincture of digitalis used was purchased from a reliable manufacturer and

[1] Read before the Association of American Physicians, Atlantic City, June 17, 1919.
[2] Digitalis Dosage, Arch. Int. Med., 1915, xvi, 1.